

controls with respect to a number of other variables, including age when person first skied, history of previous injury, height, weight, ski length, sleep during each of the previous 2 nights, and marital status.

The directions which further research might take are discussed, and strategies for prevention are outlined.

TECHNICAL NOTE

Physical forces applied to the body in skiing are the immediate and necessary cause of the injuries sustained. These in turn result from forces secondary to the characteristics of (a) the skier and his actions, (b) his equipment, and (c) the environment in which he skis. While this has long been recognized informally, it is only very recently that Sprague has treated the physical parameters of these three aspects of the system analytically (9). On the basis of this work, he has derived the following equation for the velocities which can be reached on given slopes. These agree closely with velocities observed under racing conditions (personal communication).

$$v = K \left(\frac{W (\sin \theta - K_s \cos \theta)}{A \times K_w} \right)^{1/2}$$

v=maximum attainable velocity (the "terminal velocity" at equilibrium, i.e., the speed at which wind resistance and friction of the skis balance the force of gravity), in miles per hour.

K=0.68 (with this term=1.0 the equation gives v in feet per second).

W=weight of skier, in pounds.

θ=slope angle in degrees.

K_s=coefficient of friction.

A=frontal area of skier, in square feet.

K_w=coefficient of wind resistance.

According to Sprague, for a 190-pound skier in a medium crouch (A=5.6 ft.²), with well-waxed skis and under optimum skiing conditions, K_s=0.02 and K_w=0.0009. v then varies with θ as follows:

Slope angle (degrees)	Velocity (mph)
3	24
5	34
10	52
20	75
30	92
45	110

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Clinical Study

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SKIING is one of the most rapidly growing participant sports in the world, and the rising numbers of injured skiers have become a concern both to the medical profession and to the ski industry itself. Reports of the nature of such injuries are appearing frequently in the medical literature (1-4). However, as far as we can determine, none of these have given both detailed descriptions of the injuries observed and their variation with such characteristics as age, sex, and skiing experience.

To increase understanding of the pertinence of these variables, we are reporting in this paper a study of 684 consecutive injuries which oc-

curred at a large New England ski resort. The accompanying report compares the characteristics of injured skiers with those of the skiing population at risk.

Methods

The investigations were conducted at Mount Snow, Vt., owned by the Mount Snow Development Corp. Mount Snow is one of the nation's largest ski resorts and one of the few large enough to provide an adequate case series. It has 35 miles of trails, 9 lifts with a combined carrying capacity of 12,000 skiers per hour, and slopes of every grade and qualification. Its skiers come from the entire northeastern United States. Since two of the authors (Ellison and Wolf) routinely provide emergency medical care at the base of the ski slopes in the only medical facility within 35 miles, each case could be studied intensively.

The case series was composed of persons injured while skiing at Mount Snow and receiving emergency medical care on the day of injury. It included all 684 persons meeting these qualifications during the 1960-61 ski season, which extended from mid-December to late April. Persons injured elsewhere or while using the ski lifts and those who did not request medical attention on the day injured were not included.

On arrival at the medical facility each patient was interviewed, and age, sex, and skiing experience were recorded. Skiing experience was determined by the skier's own rating of himself as a beginner, novice, intermediate, or expert. Results of the medical workup including X-ray findings were recorded in detail.

Table 1. Distribution of injuries by type, Mount Snow, Vt., 1960-61

Injury type	Number	Percent
Sprains	297	43
Fractures ¹	237	35
Lacerations and abrasions	78	11
Contusions	37	5
Dislocations	17	3
Others	18	3
Total	684	100

¹ Includes 5 cases in which a knee was also sprained (see text and table 2).

Table 2. Distribution of sprains by site, Mount Snow, Vt., 1960-61

Location	Number	Percent of total sprains
Lower extremity:		
Ankle	125	41.3
Anterior tibiofibular-fibulotalar complex	72	23.8
Anterior tibiofibular ligament only	9	3.0
Deltoid ligament	17	5.6
One or more other ligaments, unilateral:		
Incomplete tear	26	8.6
Complete tear	1	.3
Knee	118	39.2
Medial collateral ligament:		
Incomplete tear alone	73	24.2
Complete tear alone	4	1.3
With associated anterior tibiofibular-fibulotalar complex sprain:		
Ipsilateral	22	7.3
Contralateral	3	1.0
With associated lateral malleolar fracture: ¹		
Ipsilateral	5	1.7
Contralateral	0	0
2 or more ligaments, unilateral:		
Incomplete tear	6	2.0
Complete tear	5	1.7
Tarsal and metatarsal	22	7.3
Upper extremity:		
Thumb and/or hand	16	5.3
Other	7	2.3
Other sites	14	4.6
Total sprains	302	100.0

¹ Also listed in tables 1 and 3 as fractures.

In classifying multiple injuries, fractures and sprains were given precedence over other injuries also present, and lacerations were given precedence over contusions.

Results

Sprains were the most frequent injury, and these and fractures made up 78 percent of the total injuries (table 1). Sprains of the ankle and the knee accounted for 80 percent of the sprains and 36 percent of all injuries. The most common ankle sprain involved the anterior tibiofibular-fibulotalar complex (table 2). There was only one complete tear of an ankle ligament without a fracture. This was a diffuse ankle injury including a torn external collateral ligament.

Knee sprains included nine complete ligament ruptures. In seven of these, the medial collateral ligament was completely ruptured. Five of the knee sprains were associated with complete rupture of the anterior cruciate and probable damage to the medial meniscus. In 24 percent of the medial collateral ligament sprains there was also an ipsilateral anterior tibiofibular-fibulotalar complex sprain or fracture of the lateral malleolus.

Fracture of the lateral malleolus, the so-called ski fracture, accounted for 34 percent of the fractures and 12 percent of all injuries (table 3). These usually began at the level of the joint line, with the fracture line directed obliquely and posteriorly for approximately 1½ inches. Twelve of these were associated with complete tears of the deltoid ligament and talar dislocation. Fracture of both the tibial and fibular shafts was the second most frequent fracture, making up 8 percent of all injuries. Usually the tibial fracture was spiral oblique at the junction of the middle and lower thirds

Table 3. Distribution of fractures by site, Mount Snow, Vt., 1960-61

Location	Number	Percent of total fractures
Lower extremity.....	211	89.0
Lateral malleolus:		
Without dislocation of talus....	63	26.6
With dislocation of talus.....	12	5.1
With sprain of medial collateral ligament of ipsilateral knee ¹	5	2.1
Medial malleolus.....	20	8.4
Bimalleolar.....	12	5.1
Tibial shaft.....	36	15.2
Tibial and fibular shafts, unilateral.....	52	21.9
Fibular shaft.....	2	.8
Foot.....	5	2.1
Femur.....	1	.4
Other.....	3	1.3
Upper extremity.....	18	7.7
Finger.....	7	3.0
Metacarpal.....	3	1.3
Other.....	8	3.4
Trunk.....	8	3.4
Clavicle.....	3	1.3
Rib.....	2	.8
Other.....	3	1.3
Total fractures.....	237	² 101.0

¹ Also listed in table 2 as sprains.

² Difference from 100 percent is due to rounding.

extending along one-third of the length of the shaft. Very frequently this was associated with a higher, spiral fracture of the fibula, usually in the proximal one-third. Less frequent were the so-called boot-top fractures, where the leg is levered over the boot fracturing both bones more transversely at the same level. There were 36 fractures of the tibial shaft alone, but only 2 of the fibular shaft alone. The only fractured femur was in a woman 46 years old. One of the tibial fractures was the only open fracture.

Seventy-eight patients sustained lacerations. These were rarely associated with other injuries except contusions and abrasions. Twenty-eight were on the knee and lower leg, 13 on the scalp, and 21 on other parts of the head or neck.

Contusions were widely distributed over the body. Of the 17 dislocations, 9 were in the shoulder and 4 in the hand. Miscellaneous injuries included plantaris tendon rupture in three persons, and frostbite of one or more toes in two.

Age, known for 661 of the 684 injured, ranged from 6 to 60 years, with a median of 23 years. Males outnumbered females 377 to 307. The age distributions of the two sexes were very similar.

Of 450 patients for whom a skiing-experience rating was recorded, 38 percent were classed as beginners, 32 percent as novices, 28 percent as intermediates, and 3 percent as experts. A rating was not obtained for 234 of the injured, most of whom were injured at the end of the season when the ski patrol was not in regular operation. The better skiers tended to be in the 20 to 40 year age group. There was no statistically significant variation in the sex ratio of the series with age or experience.

When specific injuries were analyzed by age, tibial shaft fractures were found to occur relatively more often in the younger members of the case series (fig. 1). With increasing age there was a shift to combined tibial and fibular shaft fractures. Children under 15 years accounted for 64 percent of the solitary tibial shaft fractures. In comparison, only 17 percent of the total injured were under age 15. With increasing age there was a marked change from a predominance of tibial shaft fractures, with or without fibular involvement, to a predom-

inance of ankle fractures (fig. 2). No ankle fractures occurred among those under 10 years of age. The proportion of lateral malleolar fractures with dislocation also increased with age; there was only one such dislocation in a skier under age 20. Only 4 percent of all the lacerations were in children under 15; however, the proportion of children with contusions did not differ from the proportion of the total patients in this age group.

Among skiers with ankle sprains there was a statistically significant shift from a preponderance of females in the beginner group to a preponderance of males in the intermediate-expert category— $P < 0.01$, heterogeneity $\chi^2(5)$ (fig. 3). This was true for anterior tibiofibular-fibulotalar sprains as well as for other types grouped together. When ankle sprains were analyzed by age, there were more males than females in each age group. This change in sex ratio with experience was not seen with knee sprains; each experience group had an excess of females. The preponderance of females with knee sprains differed significantly from the sex ratio of the entire case series ($P < 0.01$). Fractures of the ankle showed a pattern similar to knee sprains, with significantly more females in each experience group ($P < 0.02$).

Seventy-two percent of fractures of the tibial

Figure 1. Number of persons with tibial and fibular shaft fractures, by age group, Mount Snow, Vt., 1960–61

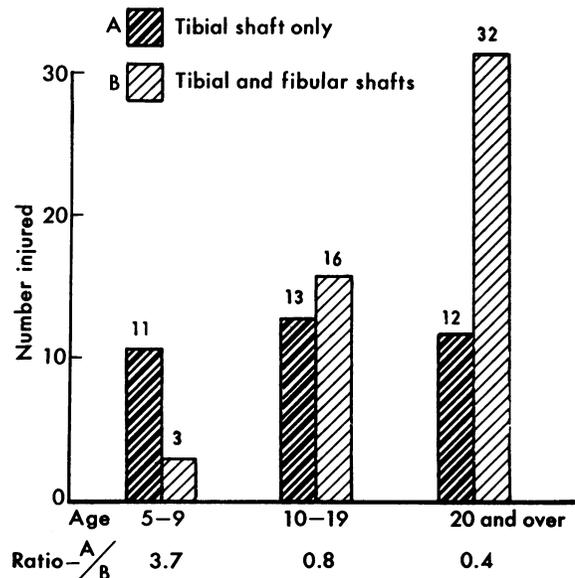
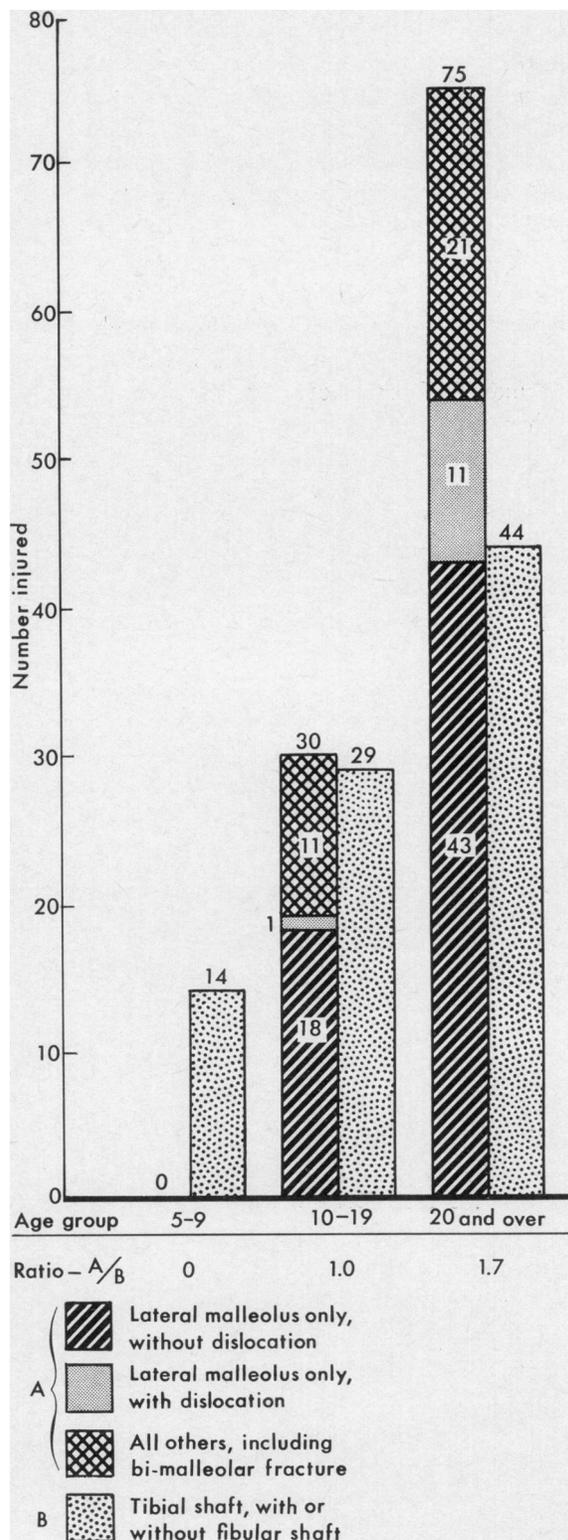


Figure 2. Number of persons with ankle and tibial shaft fractures, by age group, Mount Snow, Vt., 1960–61



shaft alone were in males, whereas 54 percent of combined tibial and fibular shaft fractures were in females. Males were significantly more frequent in the combined contusion and laceration group, accounting for 72 percent of these injuries.

Within each age group, both lacerations and contusions were more frequent in the experienced skiers. Forty-eight percent of these injuries were in intermediate and expert skiers, a statistically significant excess considering their numbers in the total case series ($P < 0.001$). No injuries other than these and ankle sprains showed a significant shift with expertise.

Discussion

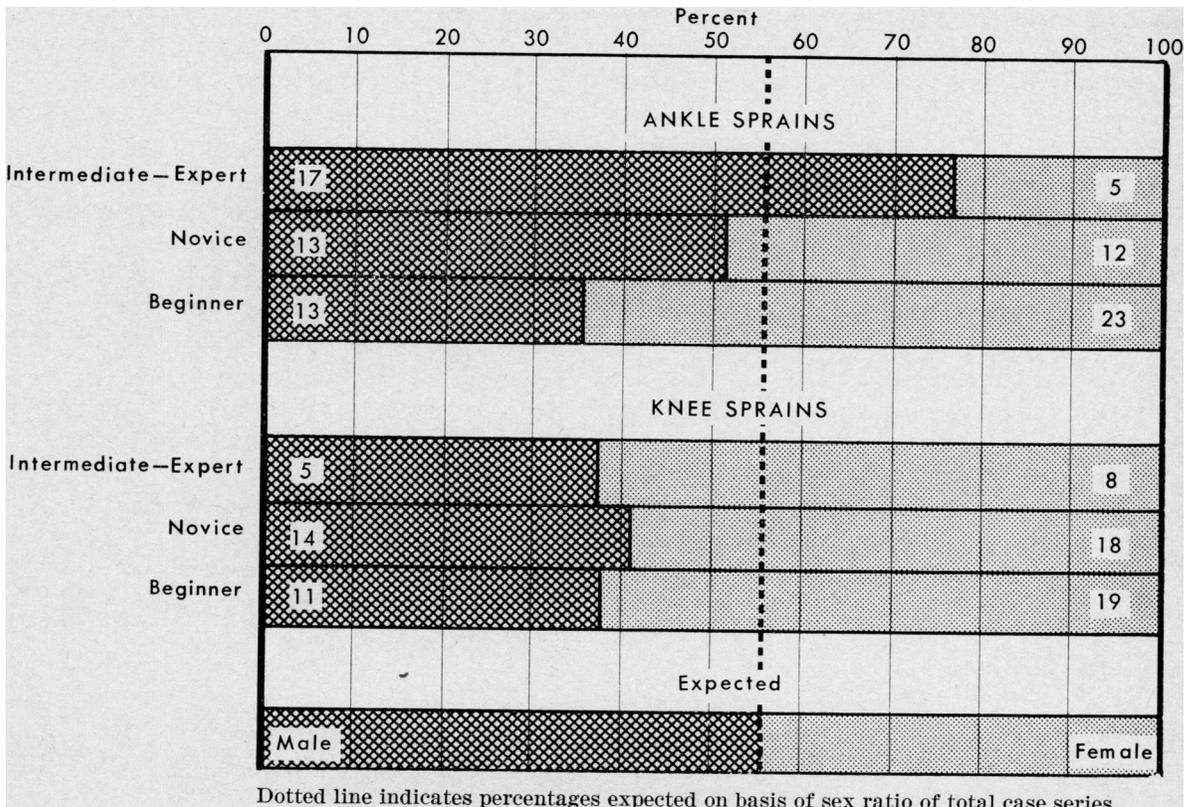
With the exception of a somewhat higher proportion of fractures, the frequency distribution of the injuries in this series was very similar to the distributions reported by Earle and co-workers from Sun Valley (1) and by Erskine quoting the National Ski Patrol (2). This similarity suggests that some factors are more fundamental in the causation of injuries

than variations in skiing conditions from area to area.

Since other workers have discussed thoroughly the diagnosis, therapy, and prognosis of most of the injuries in this and other series (1-3), we will discuss here only a few points. The only multiple-site musculoskeletal injuries observed among the 684 persons were 27 sprains of the medial collateral ligament of the knee each associated with sprain or fracture of an ankle. In all but three of these the ankle lesion was ipsilateral. Twenty-five percent (30/118) of knee sprains were associated with such ankle injuries, the identical percentage reported by Moritz (3). This combination of injuries should be recognized as an important syndrome, and its frequency emphasizes the need for careful examination of both joints when either is injured.

Lacerations and contusions may occur in two ways. The skier may collide either with his environment or with his own equipment. This distinction is important from the standpoint of prevention. Environmental modifications, such

Figure 3. Sex variation in ankle and knee sprains, by expertise group, Mount Snow, Vt., 1960-61



as the removal of rocks and trees, require different approaches than modifications of the equipment used. The series included many lacerations from sharp ski edges. Such injuries can sometimes be far more serious than generally imagined. For example, although there was none in this series, at least one castration is known to have occurred elsewhere.

Earle and co-workers (1) have recently stated, "Lacerations have become more common since the introduction of offset steel ski edges . . . [and their] discontinuance . . . would detract nothing from the sport but would prevent a number of lacerations." While this may be true, it is also possible that their use tends to prevent accidents, particularly on hard-packed and icy slopes. Many persons familiar with skiing injuries also believe that the flailing of skis and the resultant injuries may be reduced by the use of short, inelastic straps which attach the ski to the boot at more than one point, and this appears reasonable in the absence of formal evidence.

It has been known since the classical work of Bruns reported in 1886 (6) (a) that with increasing age tibial shaft fractures are increasingly accompanied by fractures of the fibula, and (b) that ankle as opposed to tibial shaft fractures are relatively rare among the young and that the ratio shifts markedly with advancing age. Our findings (figs. 1 and 2) confirm these variations for skiing fractures. Since injuries resulting from varied causes show such similar patterns, it is very likely that these shifts reflect fundamental differences in injury thresholds related to age. Protective devices such as release bindings should be designed and used with this in mind.

The sex ratio varied among injury types as noted by Boder (4), who found ankle fractures more common in females and tibial fractures more common in males. In our series ankle fractures were significantly more frequent in women, as were knee sprains and combined tibial and fibular shaft fractures. Males had significantly more tibial shaft fractures alone and more contusions and lacerations. These shifts in sex ratios from those expected were observed in all age and experience groups. The sex ratio for ankle sprains, however, shifted with expertise (fig. 3).

The female excess of knee sprains and ankle fractures may have resulted from lower injury thresholds among females and from the lack of protection offered by their release bindings, evidence of which was found in the epidemiologic study reported in the accompanying paper. The male excess in contusions and lacerations and the shift in ankle sprains with expertise can hardly, however, be attributed to variation in injury thresholds. They may have resulted from associated differences in the ways in which these groups ski.

Moritz (3, 7) suggests that rapid application of force may result in isolated fibular fractures or avulsion of the tibial insertion of the anterior inferior tibiofibular ligament. Erskine (2) feels that fractures sustained at high speeds are more likely to be in the middle or upper third of the tibia, and that slower speed accidents result in fractures nearer the ankle. Both state that with a slow application of force the ankle may be bypassed and the knee sprained. However, supporting evidence has not yet been presented, nor have these forces been measured. Experiments upon cadavers are deficient because of the absence of support from living tissue.

Although speed at the time of injury is not necessarily related to skiing expertise, some correlation might be expected. With the exception of an increase in lacerations among the more experienced and the shift in sex ratio for ankle sprains, there were no significant correlations between injury type and expertise. More specifically there was no relation between expertise and the location of tibial fractures. These findings fail to confirm the speed-injury site relationships postulated by Moritz and Erskine. However, it is known that there is a general relationship between rates of application of force and resultant injury (8), and it is quite possible that illustrations of this relationship will be found among skiing injuries. These would be expected to involve shifts in both location and nature of injury.

Summary

A clinical study of 684 consecutive skiing injuries, all those observed during the 1960-61 season at a New England resort, provided data

on frequency of specific types of injuries and on variations in type with age, sex, and skiing experience.

Sprains were the most common injury, the ankle and knee the most frequent sites. Twenty-five percent of knee sprains were associated with a sprain or a fracture of an ankle, a syndrome which has been observed elsewhere. Fractures of the lateral malleolus accounted for 34 percent of fractures and 12 percent of all injuries. Eleven percent of the injuries were lacerations and abrasions.

With increasing age there was a shift from fractures of the tibial shaft alone to fractures of both tibial and fibular shafts. Ankle as opposed to tibial fractures were uncommon among the young members of the case series, but they increased markedly with advancing age. Since fractures from causes other than skiing accidents have also been shown to exhibit this pattern, these shifts may reflect fundamental age differences in injury thresholds. In addition, there were shifts in type of injury with sex and

expertise. The data provided no evidence of a relationship between rates of application of force and type of injury, but such a relationship is possible.

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Teaching Accident Prevention

There is an immediate need for some schools to develop specialty training in accident prevention and for all schools to include accident prevention in the core curriculum and to offer separate courses on principles of accident prevention. This was one conclusion of a conference on teaching accident prevention in schools of public health conducted at the University of Michigan School of Public Health, November 8-10, 1961. The conference was co-sponsored by the Association of Schools of Public Health, the Public Health Service, and the Children's Bureau.

The conference also recognized the need for increased emphasis on research and for continued education for accident prevention.

Reports of four work sections and papers prepared for the conference are distributed by the School of Public Health, University of Michigan, Ann Arbor, as No. 100 of the Continued Education Series.

Public Welfare Amendments of 1962

The Public Welfare Amendments of 1962 (Public Law 87-543), signed by President Kennedy on July 25, emphasize rehabilitative and social services that will help recipients of Federal-State welfare programs achieve greater self-support and family stability. Briefly, the major provisions are:

Services to promote self-support. As of September 1962, the Federal Government is authorized to pay 75 percent of the costs of providing certain rehabilitative and social services to welfare recipients, as specified by the Secretary of Health, Education, and Welfare. Federal participation in the cost of providing nonspecified social services and in other administrative costs remains at 50 percent.

Child welfare services. To help States expand social and rehabilitative services to children, the present ceiling of \$25 million annually on child welfare grants will be gradually raised beginning fiscal year 1963 to a new ceiling of \$50 million annually in fiscal year 1969. Portions of these funds are earmarked for improving day care services—up to \$5 million for fiscal year 1963 and up to \$10 million for fiscal year 1964 and subsequent years.

Needy families with children. The aid to dependent children program is now called “aid to families with dependent children.”

Federal participation in aid to children in need because of an unemployed parent was extended for 5 years, until June 30, 1967. This provision, first enacted in 1961, brought employable people into a federally aided public assistance program for the first time. In States that establish community work and training programs, Federal sharing is authorized for payments for work performed by recipients of aid to families with dependent children.

Protective payments were authorized for a limited number of families in the aid to families with dependent children program who so mismanage their funds that the children's welfare is threatened. Such payments will be made to a third party who has an interest in the family's welfare. If the practices of

the family in managing its funds are not corrected, the agency will make other arrangements for the children's care.

Federal participation in the cost of foster family care for a needy child removed from an unsuitable home by court order was made a permanent provision. Also, Federal sharing in costs for such a child placed in a private child care institution was authorized for 2 years starting October 1962.

Welfare payments. To improve assistance to the aged, blind, and disabled, the temporary \$1-a-month increase voted in 1961 in the Federal matching formula for payments was made permanent, and another \$4 a month was added, effective October 1962.

The new law encourages old-age assistance recipients to contribute to their own support by permitting States to disregard a maximum of \$30 in earned income when determining the size of assistance payments.

Training welfare workers. Funds are authorized for training welfare workers through Federal and State contracts with colleges and universities. Other funds will go for fellowships, traineeships, and school facilities. The Federal Government will pay 75 percent, instead of the previous 50 percent, of expenditures in State-operated inservice training programs.

Welfare administration. The Secretary of Health, Education, and Welfare is directed to appoint a 12-member advisory council in 1964 to review the administration of public assistance and child welfare programs.

States are given an option to simplify administration by submitting a single State plan for their programs in aid to the aged, blind, and disabled and medical assistance to the aged.

Returning Americans. The temporary assistance program for U.S. citizens returning from foreign countries because of destitution, illness, or other emergencies was extended for 2 years.